Observation of Optical transients and Search for PeV-EeV Tau Neutrinos with Ashra-I

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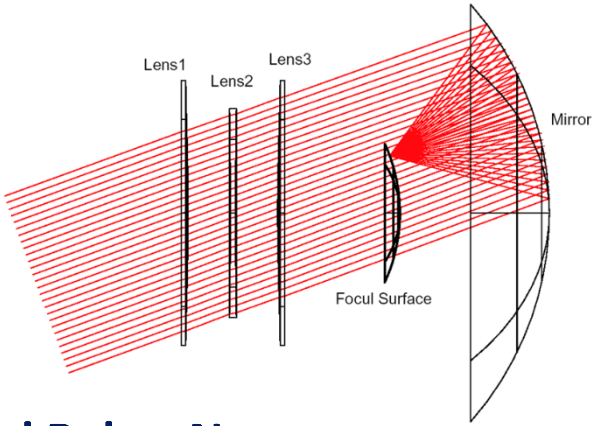
Satoru Ogawa
Toho University

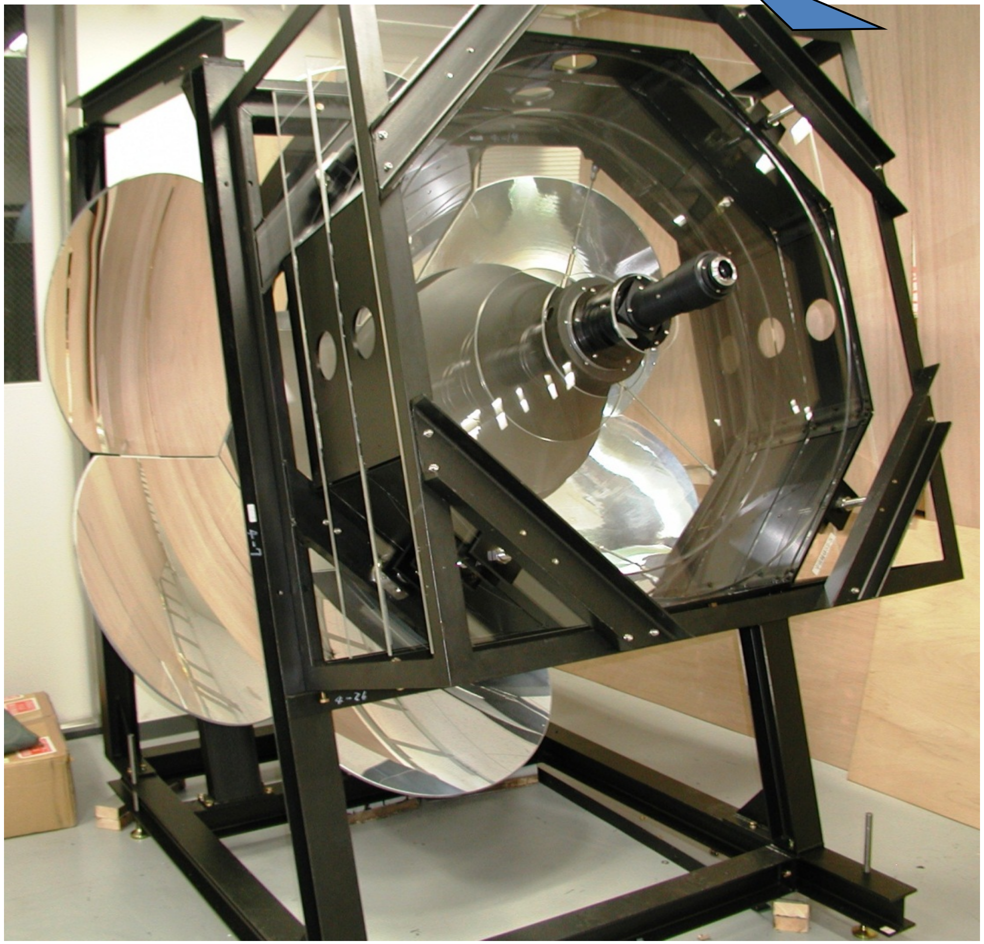
Contents

- Ashra-I detector & DAQ
- Analyses:
  Optical transients
  PeV-EeV tau neutrinos
- Prospects:
  Observation 4: Galactic Center γ
  NTA

Analysis of Ashra-I commissioning phase data are presented. Performance of the system was established. We are ready for observation 4 and for NTA

Ashra-1 Light Collector





- Optics:
  - **Modified Baker-Nunn**
- Components:
  - **Correcting lens** (1.0~1.2mϕ) with 3 acrylic cut plates
  - **Spherical mirror** (2.2mϕ) with 7 curved glass plates on adjustable tables.
  - **Photoelectric lens IT** (0.5mϕ) on focal sphere suspended with Stewart platform mechanism
  - **Mount structure** with steel channels for easy assembly

=> a few arcmin. resolution over 42deg FOV

=> affordably cost-effective

Ashra-1 Pipeline Trigger & Readout

demonstrated

Same Fine Image to Multiple Triggers

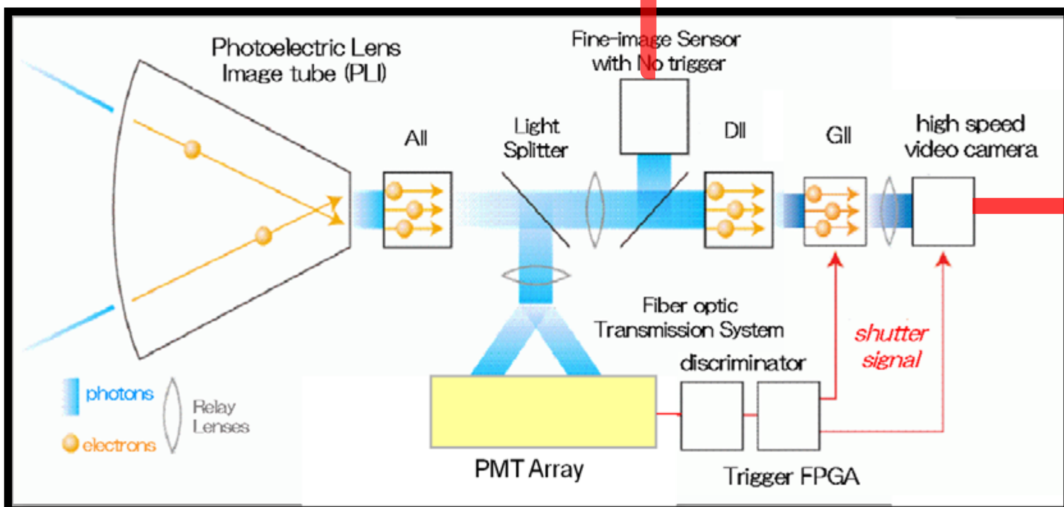
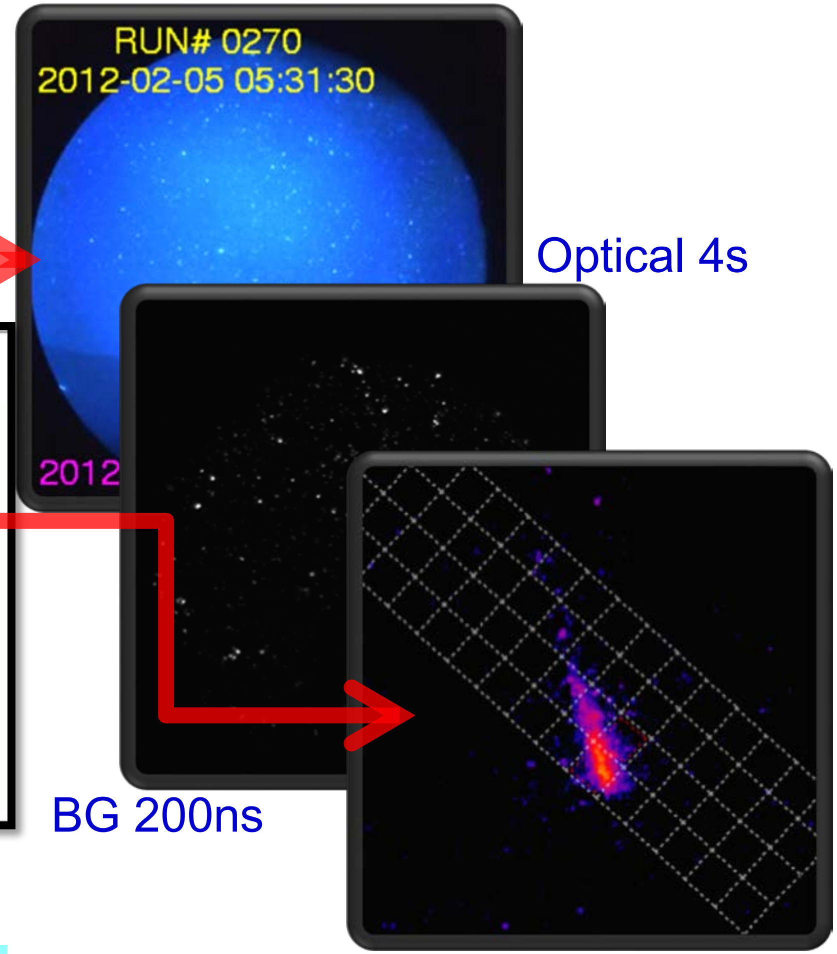


Photo-electric **I**mage **P**ipeline (**PIP**)



Optical 4s

BG 200ns

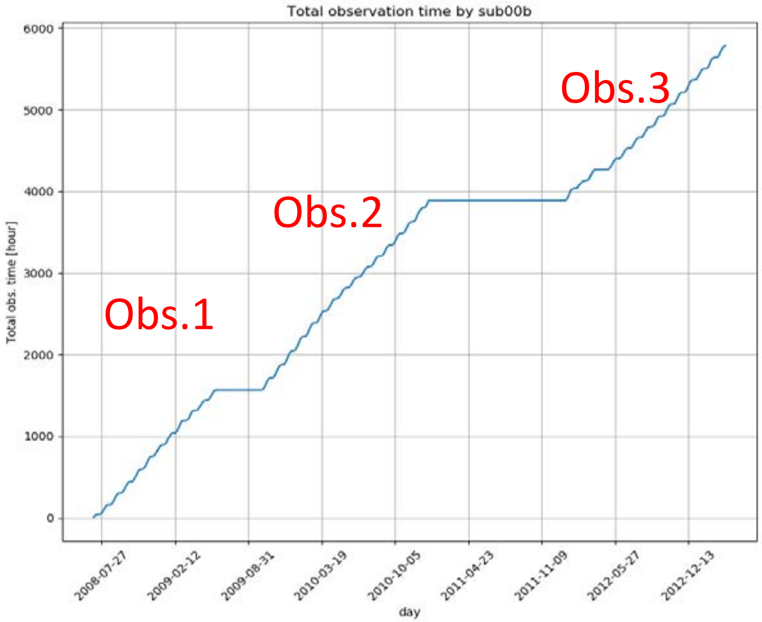
CR 200ns

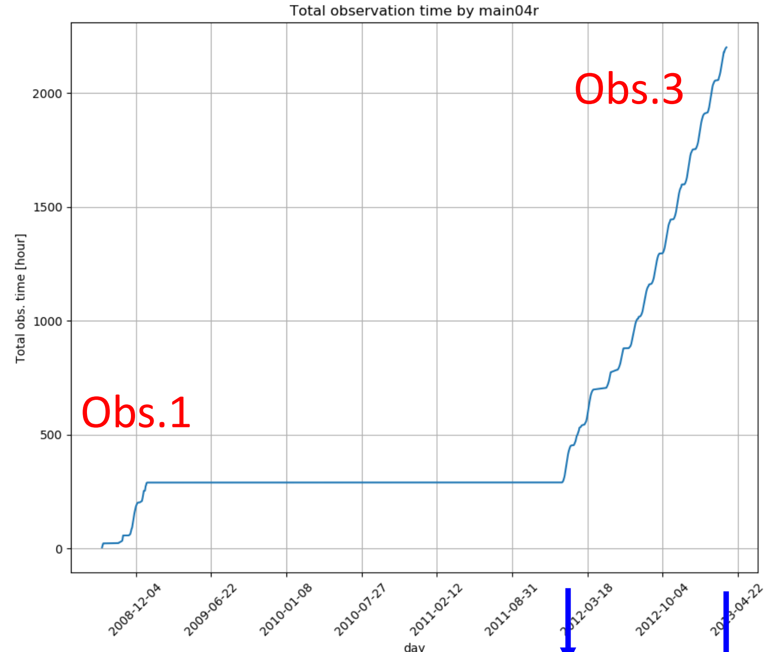
1st imaging air-shower with self-trigger

Multi-Messenger Approach with One Detector System

High Pixelation w/ CMOS → Fine Resolution

Integrated observational time in 2008-2013





June2008

Mar2013

Jan2012

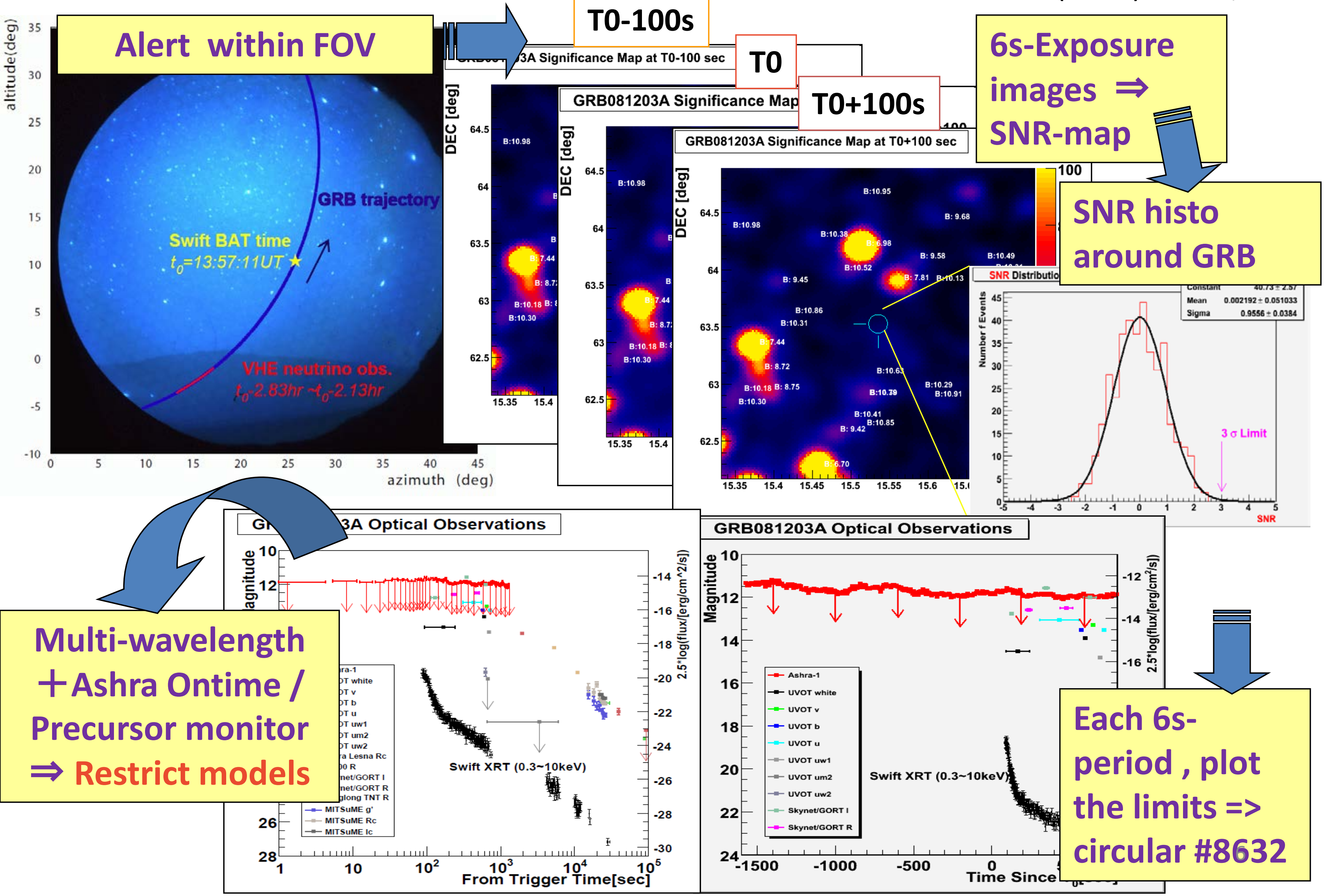
Mar2013

Optical image data for Flash search
5783 hours

Cherenkov image data for ν_τ search
1884 hours

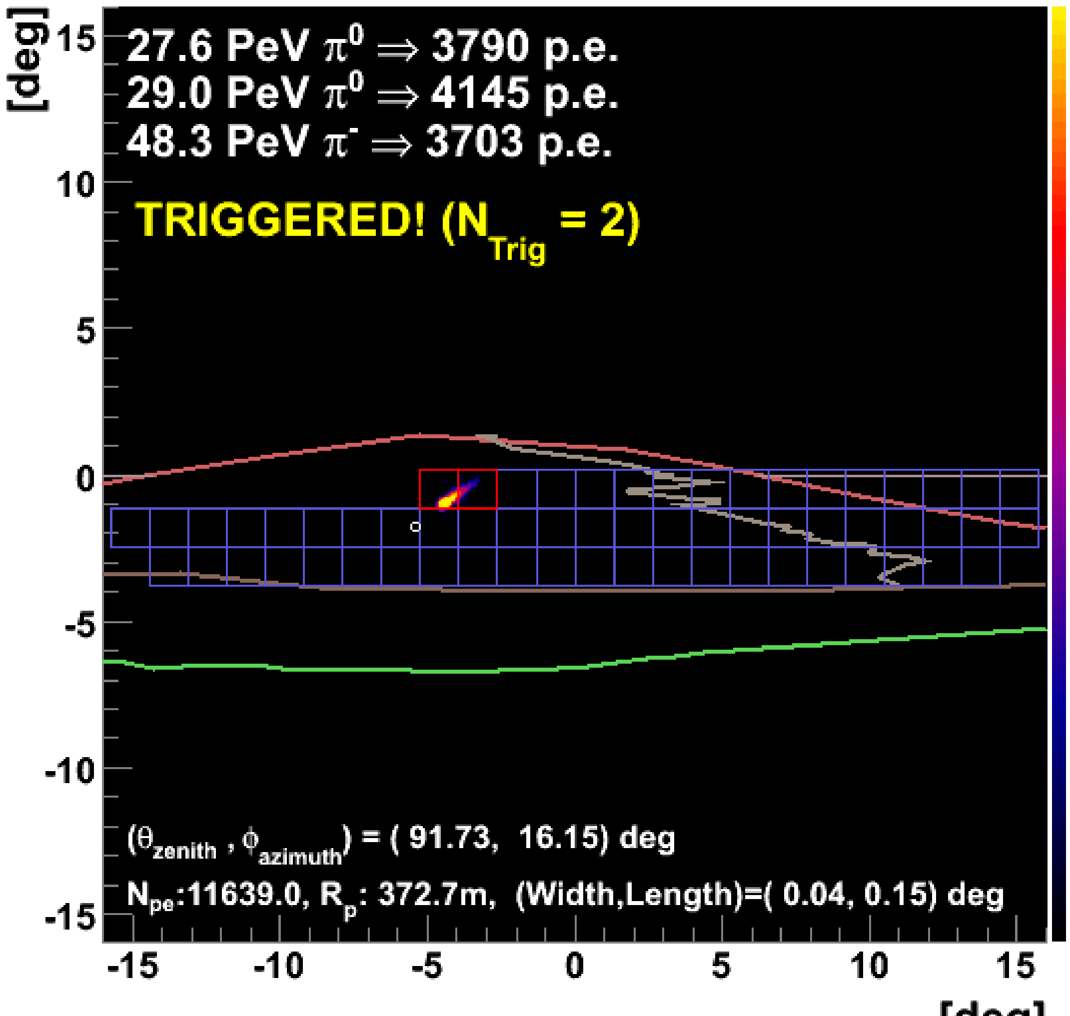
GRB Optical Flash Search (GRB081203A)

GCN circ.. 8632 (2008) Aita Y., et al.



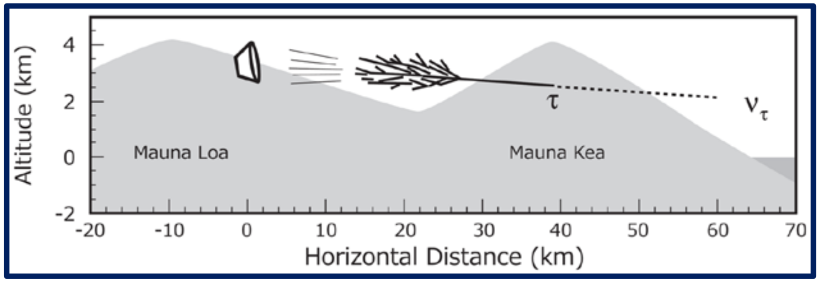
- PeV-EeV Neutrino search method -
Air Shower: Excellent Tool of Astronomy

ν_τ Simulation: $E_\nu = 10^{18.0}$ eV, $E_\tau = 10^{17.2}$ eV, Event# 000069



Tau induced Air Shower blows out

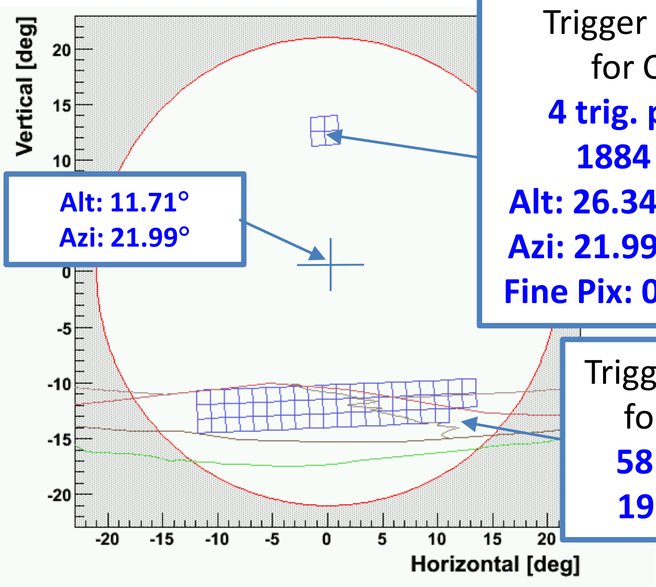
Earth Skimming Tau Neutrinos



Asaoka & Sasaki, Astropart. Phys. 41 (2013) 7-16

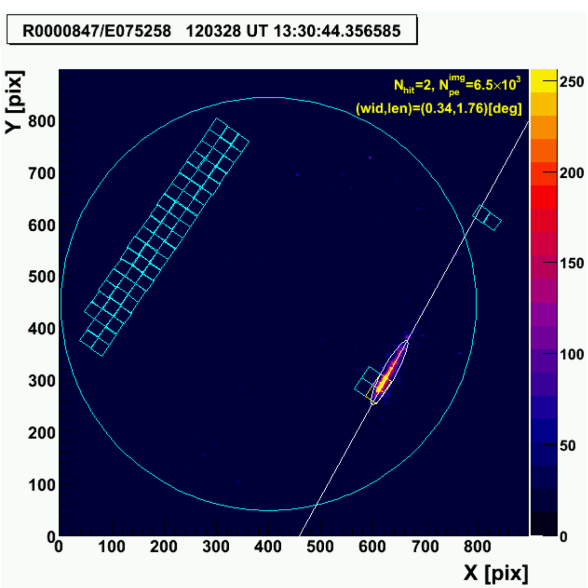
AS Cherenkov Images taken by Ashra-1

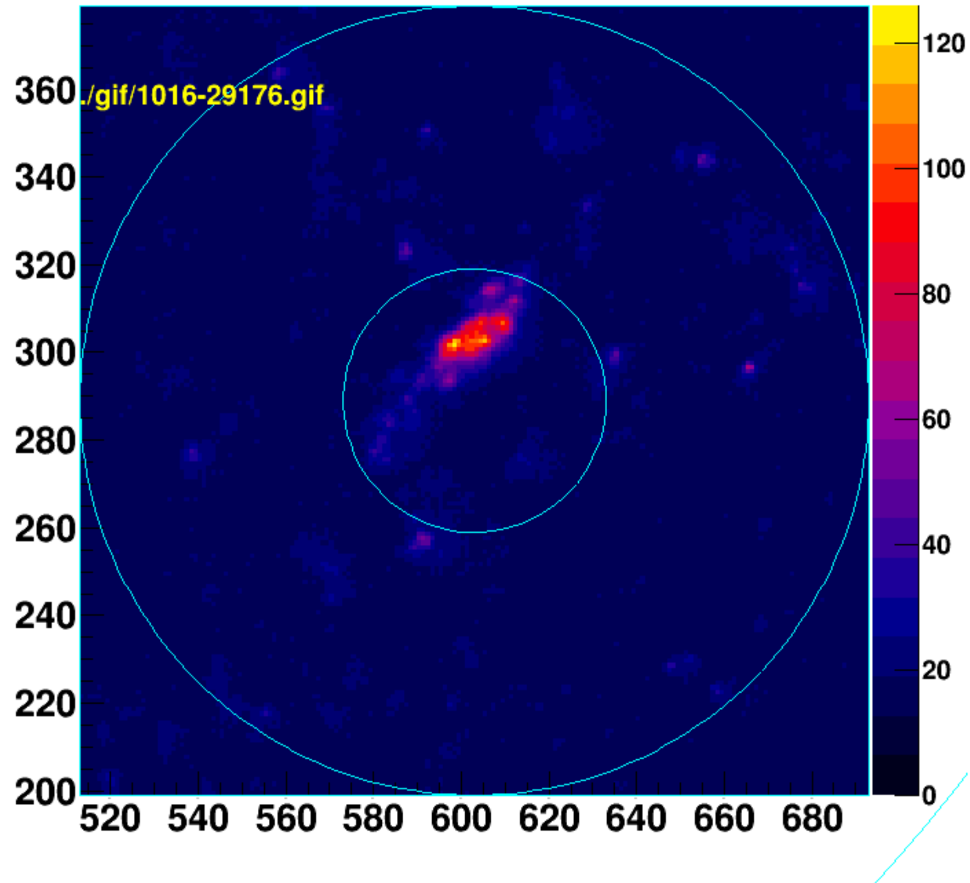
Obs03 (2012-2013):



Trigger Pixels for CR:
4 trig. pixels
1884 hrs
Alt: 26.34°±1.29°
Azi: 21.99°±1.29°
Fine Pix: 0.05°/pix

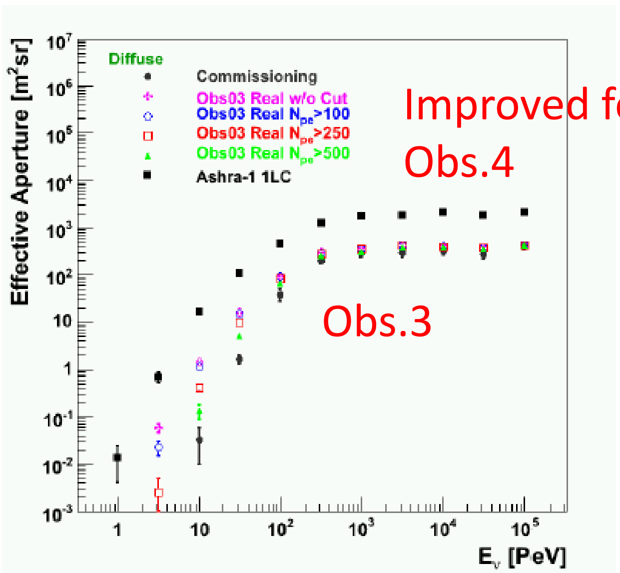
Trigger Pixels for Taus
58 pixels
1950 hrs





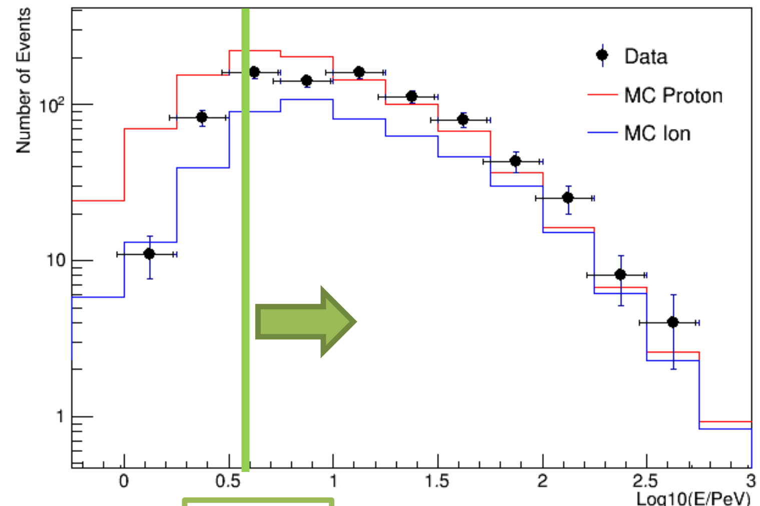
CR Observed Energy Spectrum

Effective aperture



Obs03 events

MC normalization by CR flux.



3PeV

824 events (1884 hrs)

Used for ES-ν_τ search

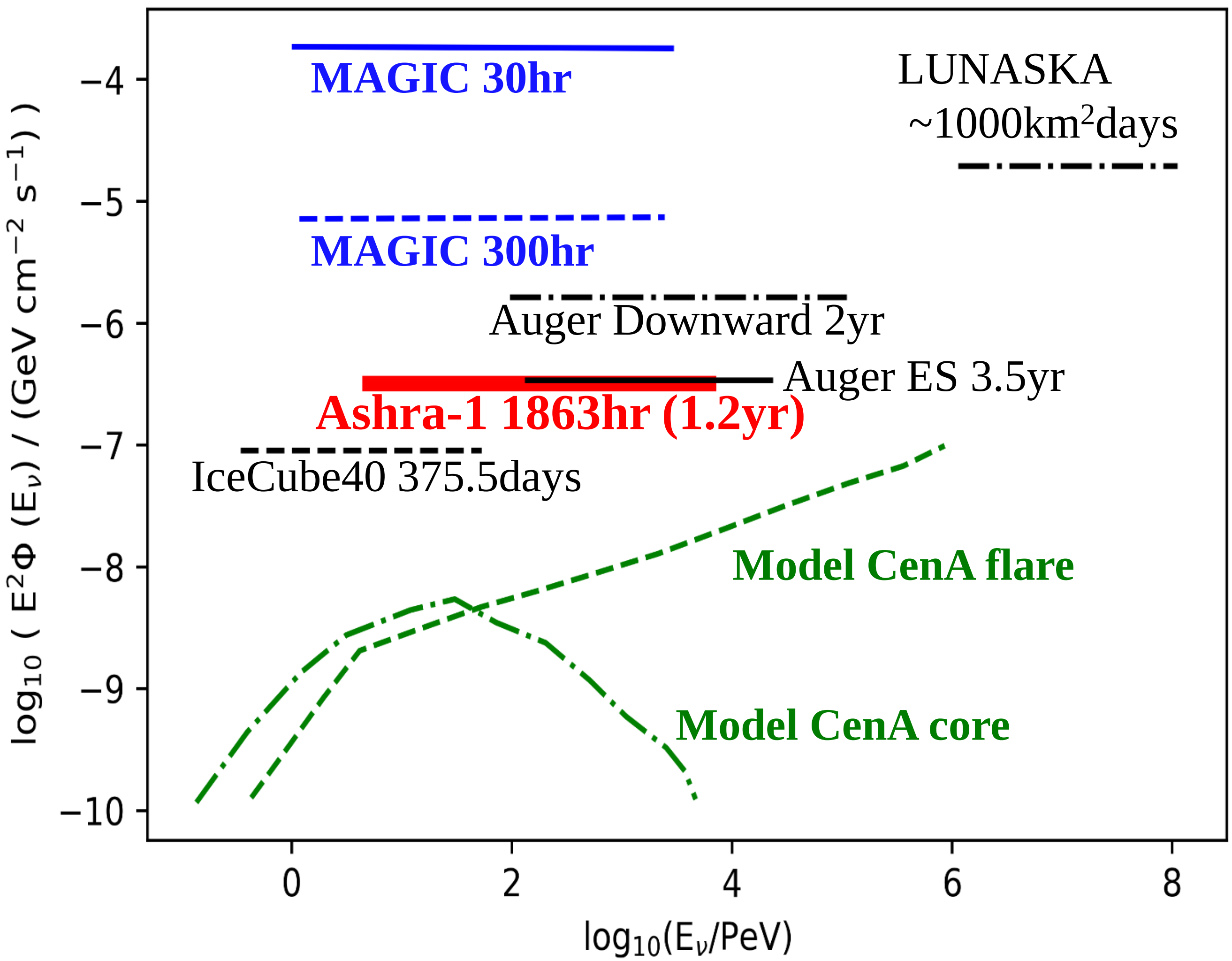
Source of Systematics	Error [%]
Trigger Threshold	19
Atomsphere & Optics	21
DAQ Efficinecy	6.3
Weather Condition	6.4
Sensitivity Total	30
Fine Image Gain	30

Detectability of τ shower confirmed

Become negligible due to LED flasher calibration

Comparison of ES Tau Neutrino Flux Limits

Null result (1863 hrs) of ES-ν_τ search



Auger (2012).
GI-Astro-Ph.HE, 1–21.

MAGIC (2018).
Astropart.Phys.102,77-88.

LUNASKA (2011).
MNRAS 410(2), 885–889.

IceCube (2011).
ApJ 732(1).

Cuoco (2008).
PRD 78(2), 1–5.

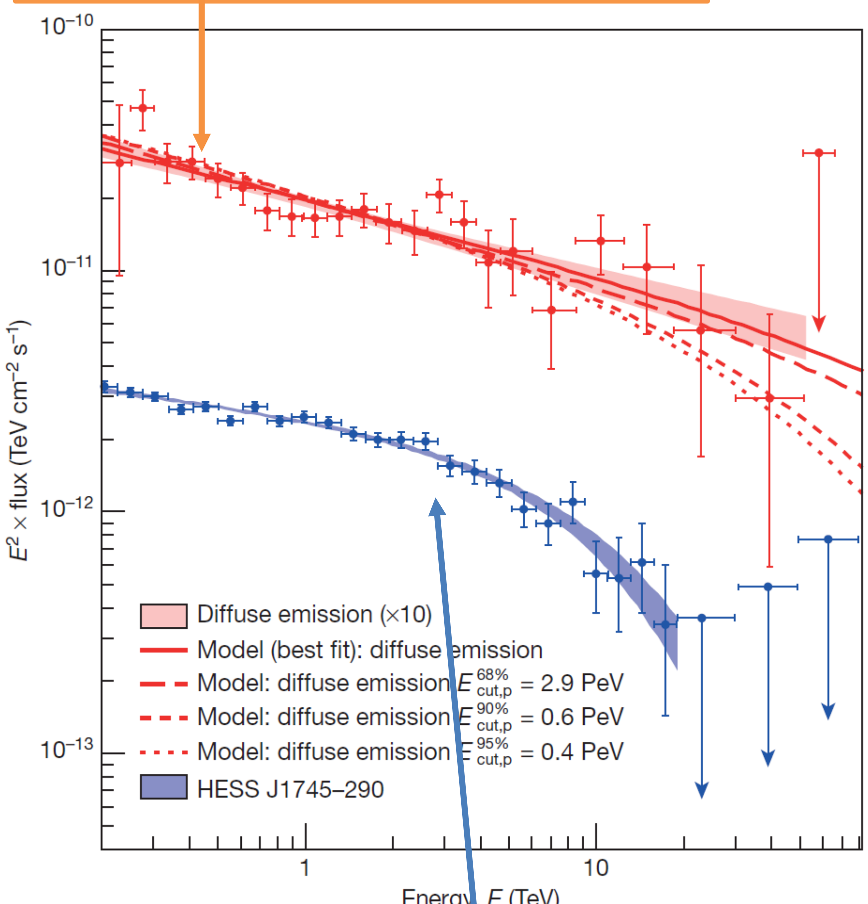
Kachelrieß (2009).
New Journal of Physics, 11.

Ashra−1 Obs03 best PS sensitivity for ES−ν_τ

Next step:
Target Example of VHEPA: Galactic Center

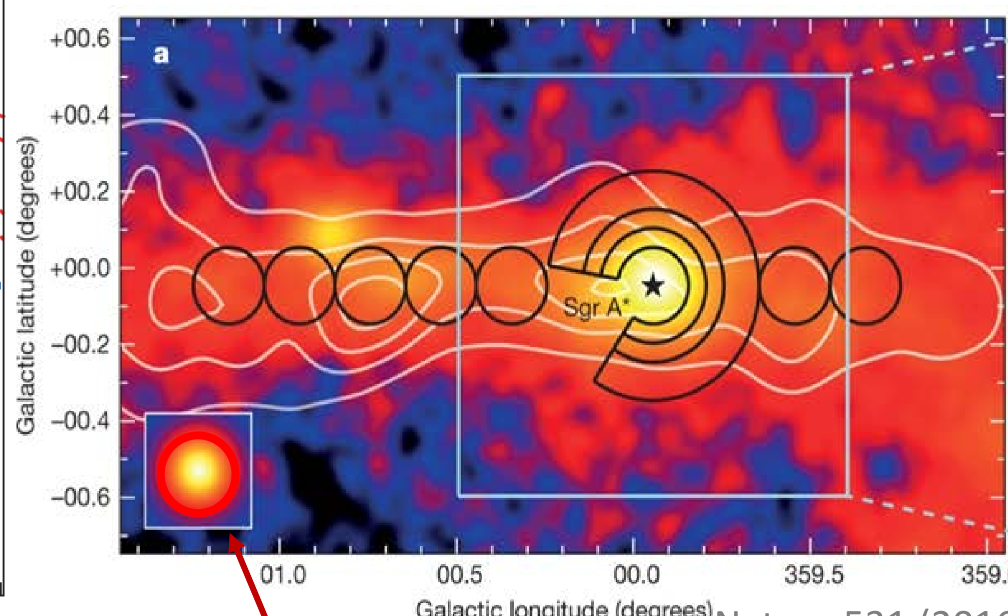
To clearly fix it, the detector is required to:
1) **γ-ray/ν multiple observation**
2) 0.1 deg. resolution like IACT
3) good sensitivity for E_γ > 50 TeV
-> Ashra/NTA meets.

Diffuse emission from the GC without a perceivable cutoff



Point source emission with a 10 TeV cut-off

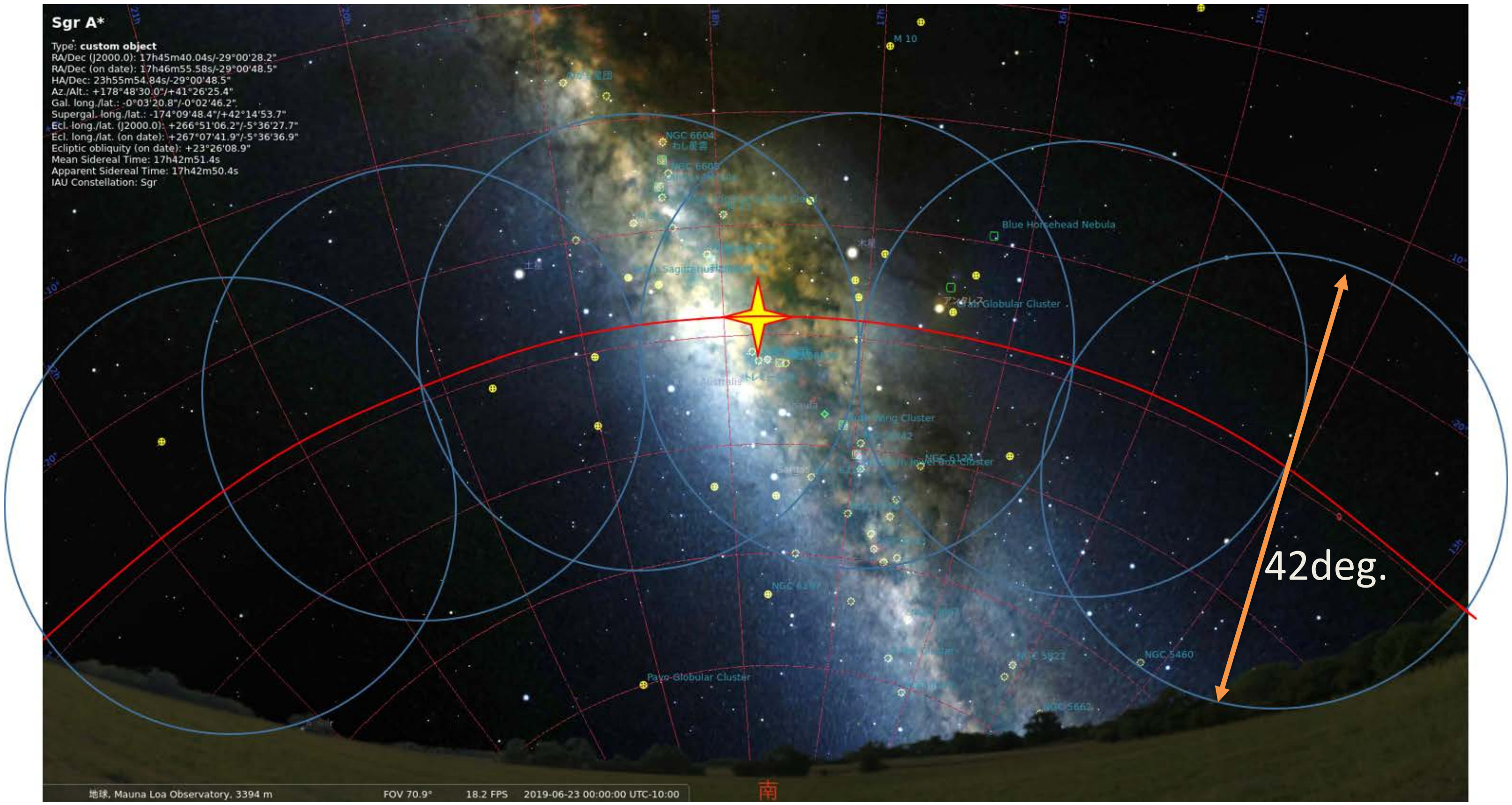
HESS GC observation 227 hours / 10 years
=> Need monitor obs. with wider FOV IACT.



Nature 531 (2016)

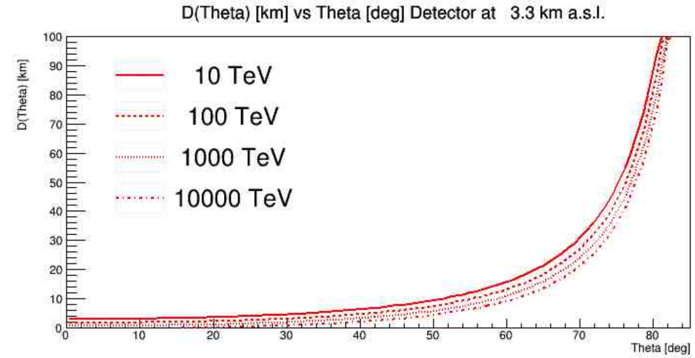
HESS PSF

Layout of Ashra-1 FOVs in Obs.4



Simulated southern sky at the Ashra-1 Mauna Loa site at 0:00 on June 23, 2019.
The star mark indicates the location of the galactic center (GC).
The track of GC (arc) and the FOV of the rearranged Ashra-1 light collectors (circles) are also shown.

Advantage of Ashra-1/NTA imaging GC γ



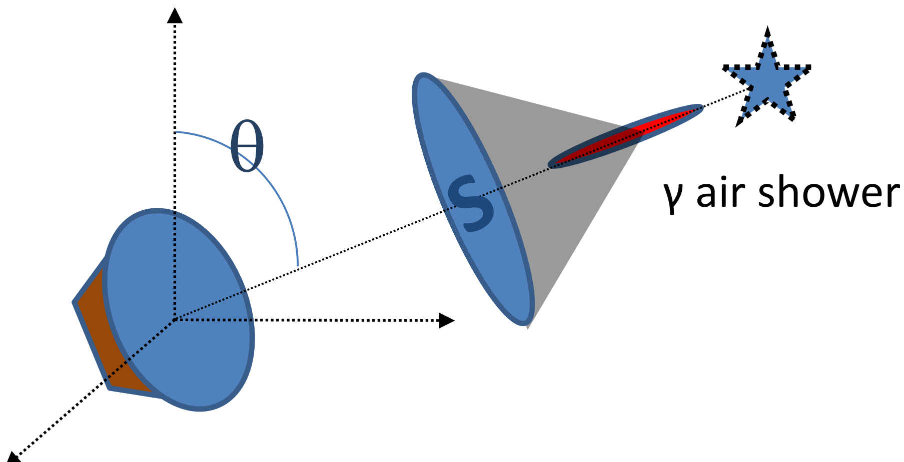
Ashra-1/NTA

Effective detection area S :

S increase as θ due to far Cherenkov

Cherenkov light : small attenuation

⇒ more advantage for higher Energy



GC survey (HESS : 227hr/10yr)

T = 1150～1900 hr/yr (θ = 48~90°)

S = 0.3 km^2/1unit @10 TeV (θ = 70°)

12 km^2/1unit @1 PeV (θ = 70°)

Ground 2D particle array

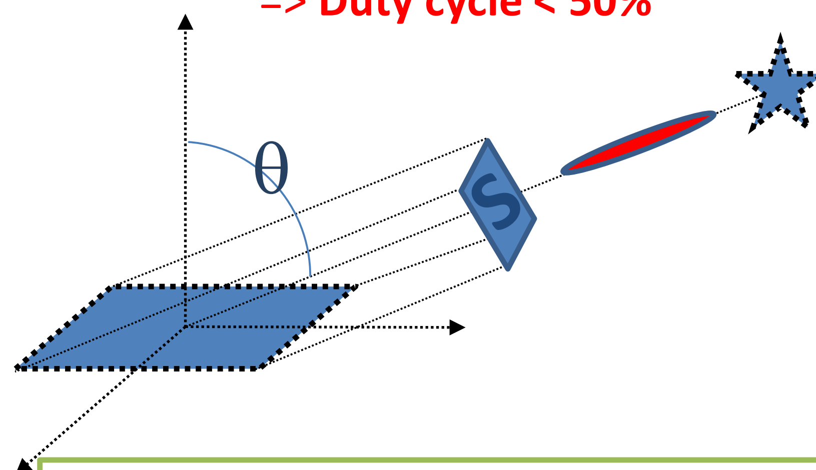
$S = S_0 \cos\theta$

Shower particle electron :

severe attenuation

=> Only effective θ < 45°

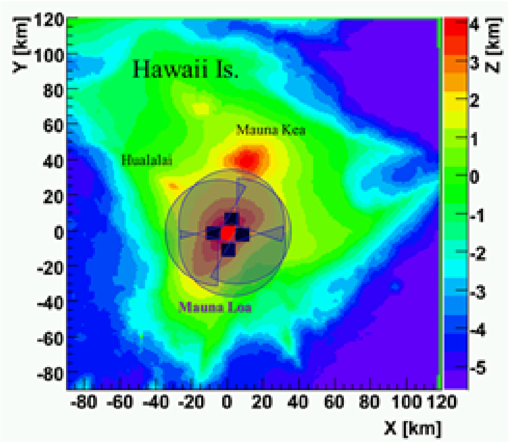
=> Duty cycle < 50%



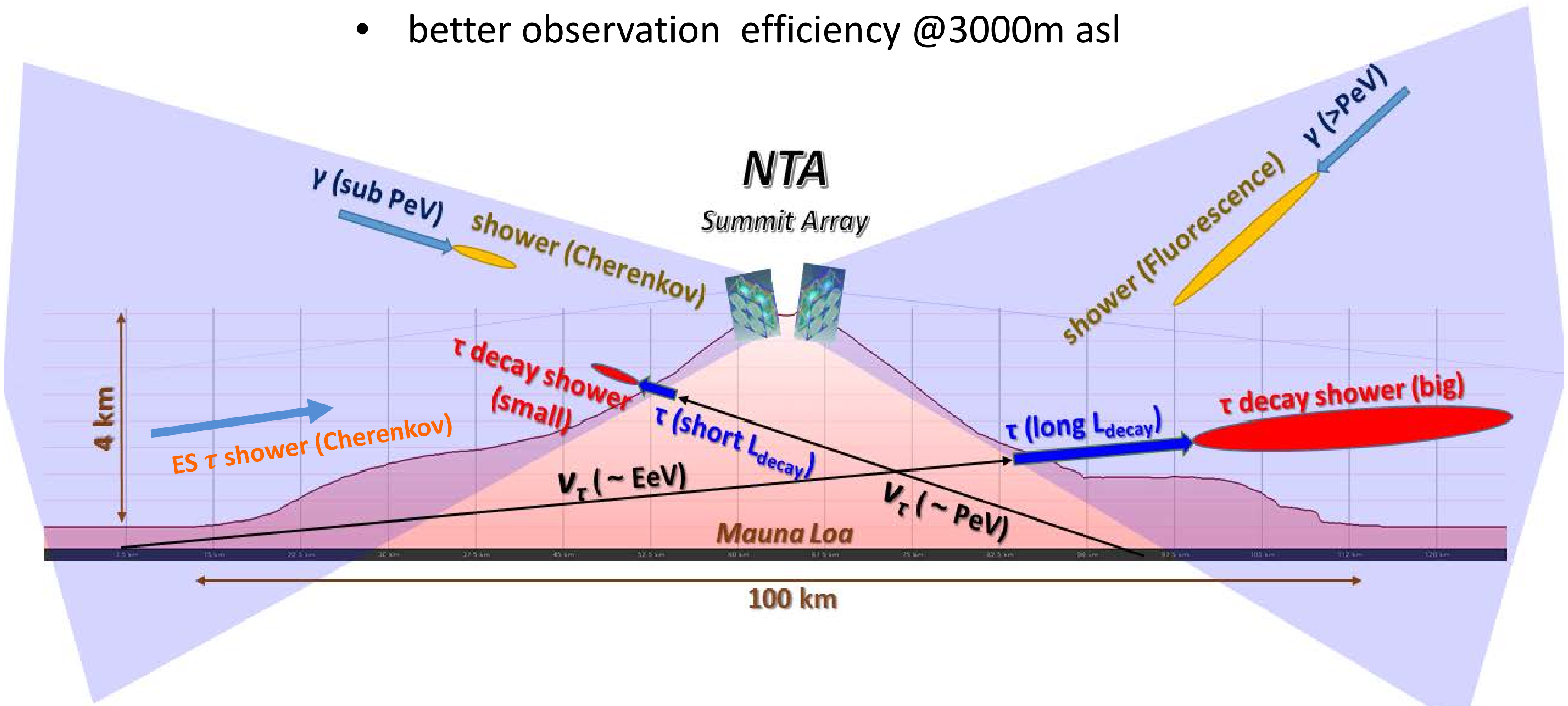
T = 2300 hr/yr (θ < 45°) @S. lat.16 deg

S < 0.2 km^2 (500m 2D array)

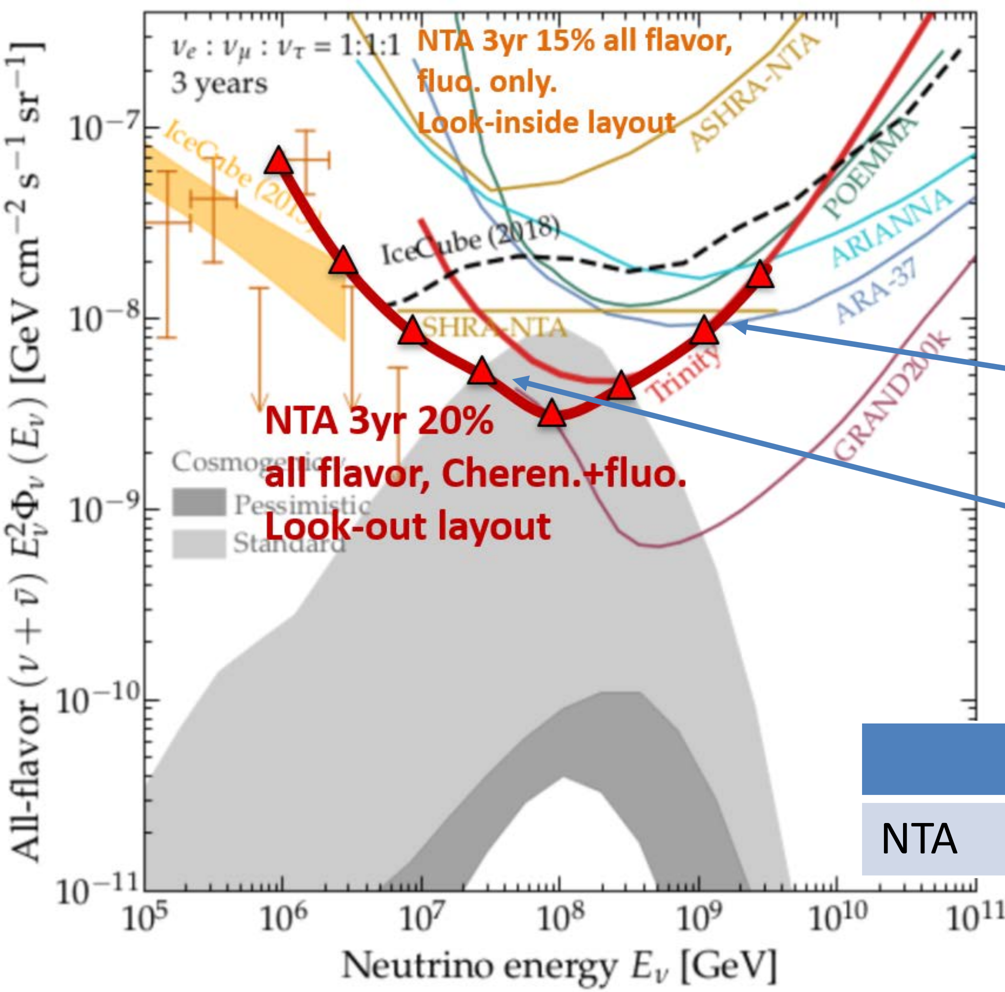
Next next step: NTA summit array detection of ν / γ-ray / CR



- τ decay length : $L_\tau \sim 50\mathrm{m}\ (E_\tau/\mathrm{PeV})$
  ⇒ can watch nearler 1∼10PeV AS max
- lower detection E thereshold
- better observation efficiency @3000m asl



NTA diffuse ν sensitivity: with Cherenkov & fluorescence light



NTA most sensitive for 1PeV-100PeV ν

Clear test:
IceCube PeV ν extension
Cosmogenic ν

Far ES tau neutrino Cherenkov observation

Near ES tau neutrino fluorescence observation

Thanks to look-out layout

	aper.	height	Fov	Resol.
NTA	10 m^2	**3** km	360° x**30**°	**0.125**°

Conclusions

- Precursor search in 84 GRB candidates from 5783 hours optical image data is in progress.
- PeV-EeV cosmic-ray spectrum was successfully obtained from 1884 hours of Cherenkov image data.
- PeV-EeV tau neutrino point source flux is limited to be:

$$E_{\nu_\tau}^2 \cdot \phi(E_{\nu_\tau}) < 3.2 \times 10^{-7} GeV\, cm^{-2} s^{-1}$$

  from 1863 hours of Cherenkov image data toward Mauna Kea and the earth crust around it.
- Successfully demonstrated Ashra unique features.
- Observation 4: Dedicated observation for Galactic center γ-rays is proposed using 6 LCs, which allows putting the Galactic center into FOV for more than 1000 hours/yr.
- NTA to look out at the summit: enjoys huge acceptance for far Ceren. ES-ν_τ events. => the best ν sensitivity in PeV-EeV region with IACT reso.

Please join us !